Oil concentration differences among sunflower achenes and feeding preferences of red-winged blackbirds

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Abstract The effect of differences in oil concentration among sunflower achenes on consumption preferences exhibited by red-winged blackbirds (*Agelaius phoeniceus*) were investigated. Male birds were given 2-cup tests between samples of intact (experiment 1) or hulled (experiment 2) seeds with various oil contents. The results showed that birds could discriminate among achenes when differences in oil concentration were as little as 5% (g/g). High-oil achenes were preferred. When hulls were removed, discrimination was significantly impaired. Oil differences among sunflower varieties and/or morphological characters associated with oil content (e.g. hull thickness) probably influence bird depredation.

Keywords Blackbird: depredation; red-wing; sunflower; varietal resistance

Introduction

Damage by passerine bird species, including red-winged blackbirds (*Agelaius phoeniceus*), house sparrows (*Passer domesticus*), and goldfinches (*Carduelis tristis*), to oilseed sunflower can be severe (Besser, 1978). In part, this reflects the long period during which sunflowers are susceptible to depredation: damage can occur at any time from early seed development (about 5 days after bloom) until harvest (Cummings *et al.*, 1987).

One means of reducing bird damage to sunflowers may be the development of bird-resistant or tolerant varieties. This approach has been used with maize (Dolbeer, Woronecki and Mason, 1988), sorghum (Bullard, York and Kilburn, 1981), and pears (Greig-Smith *et al.*, 1983; Summers and Huson, 1984). As with these other crops, efforts to develop bird-tolerant varieties of sunflower have emphasized morphological and chemical traits.

Morphological features of sunflower thought to increase resistance include concave heads, long bracts, ground-facing heads, head-to-stem distances > 15 cm, and seeds with tough fibrous hulls held tightly in the head (Parfitt, 1984). Chemical features thought to increase resistance (possibly via taste repellency) include anthocyanins present in the seed hulls of some varieties (Dolbeer *et al.*, 1986; Mason *et al.*, 1986). However, it has not been ascertained whether bird-resistant sunflower varieties suffer reduced damage because of morphology, chemical repellency, or low oil content. Commercial varieties have oil contents as high as 50% (g/g), whereas potentially resistant cultivars have oil contents that range between 30 and 40% (g/g; Mason *et al.*, 1989a). Red-winged blackbirds are capable of discriminating among sunflower meal samples that differ in oil by as little as 15% (Mason *et al.*, 1989a), and field data suggest that resistant cultivars escape damage only when plantings of high-oil commercial varieties are accessible (Mason *et al.*, 1989b). The present experiments were designed to test whether red-winged blackbirds could discriminate among sunflower achenes having different oil concentrations (from approximately 32 to 50% g/g), and whether high-oil varieties were preferred.

Materials and methods

Subjects

Red-winged blackbirds are the major vertebrate pest of sunflower in North Dakota (Holthem, DeHaven and Fairaizl, 1988). Therefore, 60 adult (65–80 g) males were decoy-trapped (US Fish and Wildlife Service, 1973) near Fargo, ND, and kept in an outdoor cage (10 × 10 × 3 m) for 2 weeks before experimentation (September, 1989). After

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the 2-week adaptation period, birds were housed individually in cages (1.8 × 1.5 × 1.8 m) next to a cornfield on the experimental farm at North Dakota State University, Fargo ND.

Except during test sessions, birds were provided free access to a diet of Purina Flight Bird Conditioner (33.3% g/g), millet (33.3% g/g) and sunflower achenes (33.3% g/g; variety: Jacques 501, oil content 47% g/g). Feed was presented in two 230 ml plastic cups positioned as described below. Water and grit were provided in pans on the floors of the cages.

Achene characteristics

Four experimental sunflower varieties under development at North Dakota State University served as stimulus foods. The varieties and their oil contents as determined by nuclear magnetic resonance were: ND83153-1 (NdC), 32.1% (g/g); ND83223-19 (BRS), 36.8% (g/g); Seed Tec 1 (ST1), 44.1% (g/g); and Seed Tec 2 (ST2), 49.5% (g/g). Variance around these mean values was negligible (i.e. $<0.05\%$). With the exception of BRS, all of the varieties had achenes of about the same size and colour (black). BRS seeds were grey and appeared slightly longer than the others. The mean length, width, and thickness of 25 randomly selected achenes from each variety were therefore measured and evaluated as described below (Analyses).

In addition to determination of oil content, percentage crude protein (Ferrari, 1960), acid-detergent fibre (Van Soest, 1963), percentage dry matter (Tatchell, 1989), gross energy (cal g^{-1}) (Tatchell, 1989), and percentage soluble tannins (Bullard *et al.*, 1989) were determined for all seed samples.

Experiment 1

Thirty blackbirds were selected randomly, weighed, and assigned to two groups. One day after selection, the pretreatment period began. Within 1 h of sunrise on each of 4 consecutive days, maintenance diet was removed from all cages, and each bird was presented with two 230 ml plastic cups, each containing 15 g Jacques 501 (J501), a commercial sunflower variety with an oil content of 47.0% (g/g). Cups were positioned on either end of a 16 cm piece of plywood attached to the end of a 45 cm wooden strut extending from the east wall of each cage, 1.4 m from the floor. After 1 h, the cups were removed from the cages, and the remaining achenes were weighed. Maintenance diet was then returned to the cages. Spillage was not measured because it was impractical to do so accurately.

A 6-day treatment period immediately followed pretreatment. On each day, all birds were given a test between two of the sunflower varieties in the same manner as in the pretreatment period. Over the course of testing, each group received a different (opposite) order of all pairwise comparisons among seed samples: group 1 received low to high oil concentrations (i.e. NdC vs BRS, NdC vs ST1, NdC vs ST2, BRS vs ST1, BRS vs ST2, ST1 vs ST2), whereas group 2 received high to low concentrations. Cup positions were randomized, but individual birds were not given different random orders of achene pairs because order of presentation effects had not been observed in similar, previous work (e.g. Mason *et al.*, 1989a). Daily temperatures, cloud cover and precipitation were recorded. At the end of the experiment, all birds were released.

Experiment 2

Procedures were identical to those described for experiment 1, except that hulled (rather than intact) and crumbled (2–3 mm particle size) achenes were presented to the remaining 30 birds during pretreatment and treatment.

Analyses

Results were assessed using methods appropriate for the balanced incomplete block (BIB) designs (Cochran and Cox, 1957) described above. Specifically, consumption by each group was analysed separately within each of the two experiments. In addition, treatment days represented independent incomplete blocks and each bird was assumed to provide an independent replication of the BIB design. Subsequent to these omnibus procedures, adjusted treatment means were tested for significance using Bonferroni *post-hoc t* tests ($p \leqslant 0.05$) (Games, 1971).

Because there were slight but consistent differences among varieties in achene dimensions, a two-factor ANOVA was used to evaluate whether any of the differences were significant. Tukey HSD tests (Winer, 1962) were used to isolate significant differences among means ($p<0.05$).

Rank-order correlations were computed to quantitate relationships between the chemical characteristics of achene varieties and overall mean consumption (i.e. consumption collapsed over time and presentation pairings).

Results

Achene characteristics

All varieties had approximately the same percentage dry matter and no detectable level of soluble tannin (*Table 1*). Both SeedTec varieties had lower percentage ash and protein but higher gross energy than BRS. BRS had higher gross energy but lower ash and protein values than NdC. With regard to percentage acid detergent fibre, the highest values were recorded for ST1 and ST2, followed by NdC, and then BRS.

Analysis of achene dimensions revealed significant differences among varieties ($F=8.5$; 3,96 d.f.; $p<0.0001$), and a significant interaction between varieties and dimensions ($F=6.3$; 6,192 d.f.; $p<0.00001$). *Post-hoc* tests showed that BRS achenes were slightly, albeit significantly, longer than the other varieties ($p<0.05$); otherwise, there were no significant differences (*Table 2*).

Table 1. Results[a] of chemical analyses on achenes from the four varieties used in experiments 1 and 2

	Sunflower variety			
Analysis	NdC	BRS	ST1	ST2
Dry matter (%)	94.4	93.7	94.7	95.4
Ash (%)	5.2	4.7	3.9	3.0
Gross energy (cal g^{-1})	6.7	6.8	7.0	7.5
Crude protein (%)	32.5	30.5	27.7	21.1
Acid detergent fibre (%)	13.5	13.4	18.9	16.6
Tannin (%)	—	—	—	—

[a]Values represent mean percentages of duplicate samples. Variance was negligible (i.e. < 0.1%)

Table 2. Mean dimensions[a] (mm) of achenes from the four sunflower varieties

Variety	Length	Width	Thickness
NdC	7.9	4.6	2.6
BRS	8.7	4.7	2.5
ST1	7.9	4.4	2.5
ST2	7.9	4.3	2.7

[a]Values represent mean dimensions of 25 achenes from each variety. Variance measures were neglible (≤ 0.1 mm)

Experiment 1

For group 1, average consumption among varieties differed significantly ($F = 19.46$; 3,87 d.f.; $p < 0.001$). For individual birds, total daily consumption from cups did not differ ($p > 0.50$); however, overall consumption among birds during the 6 treatment days did differ significantly ($F = 3.44$; 14,87 d.f.; $p < 0.001$). *Post-hoc* tests showed that consumption of NdC was significantly less than that of the other three varieties, and that consumption of BRS was significantly lower than that of ST2 (*Figure 1a*). Average total daily consumption during the pretreatment period (2.14 g) was nearly identical to that during the treatment period (2.12 g).

As for group 1, group 2 average consumption among varieties differed significantly ($F = 5.59$; 3,87 d.f.; $p < 0.01$) and increased with increasing oil concentration (*Figure 1b*). However, the only significant differences in consumption were those between NdC and ST1 and ST2. There was no significant variation ($p > 0.50$) in either total consumption among birds during the treatment period or in total daily consumption among days within birds. Average total daily consumption during the pretreatment period (2.18 g) was very similar to that during the treatment period (2.08 g).

When the overall mean consumption of both groups was computed (*Figure 1c*), ranked, and correlated with achene chemical characteristics, both oil content and gross energy were perfectly and positively correlated with consumption (r values = 1.0; 2 d.f.; $p < 0.0001$). Conversely, percentage ash and percentage crude protein were perfectly and negatively correlated with consumption (r values = − 1.0; 2 d.f.; $p < 0.0001$). Neither percentage dry matter nor percentage acid detergent fibre were significantly associated with consumption (p values > 0.20).

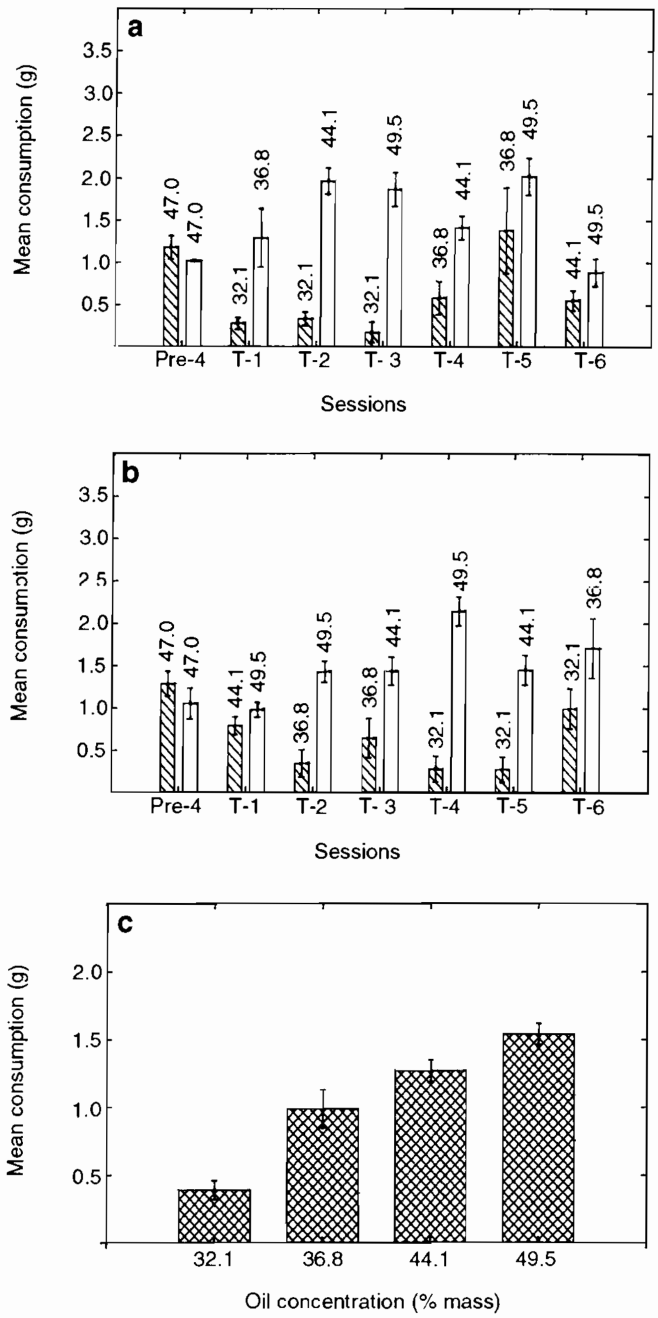

Figure 1. Experiment 1. a, Consumption of intact sunflower achenes by group 1 birds on pretreatment day 4 and treatment days 1–6. With the exception of pretreatment day 4 (Pre-4), striped bars represent consumption of the low-oil variety in each pair, and open bars represent consumption of the high-oil variety. b, Consumption of intact sunflower achenes by group 2 birds on pretreatment day 4 and treatment days 1–6. Striped and open bars represent consumption of low- and high-oil varieties, respectively, as described above. (c) Overall mean consumption by both groups of all achene varieties, collapsed over time and presentation pairings. Numbers above bars represent achene oil concentrations (percentage g/g). Capped vertical lines represent standard errors of the means. Oil contents: J501, 47%; NdC, 32.1%; BRS, 36.8%; ST1, 44.1%, ST2, 49.5%

Experiment 2

Complete consumption data sets were obtained from seven birds in each of the two groups; only these data were analysed. The other eight birds in each group died or escaped during a severe rainstorm that occurred during the

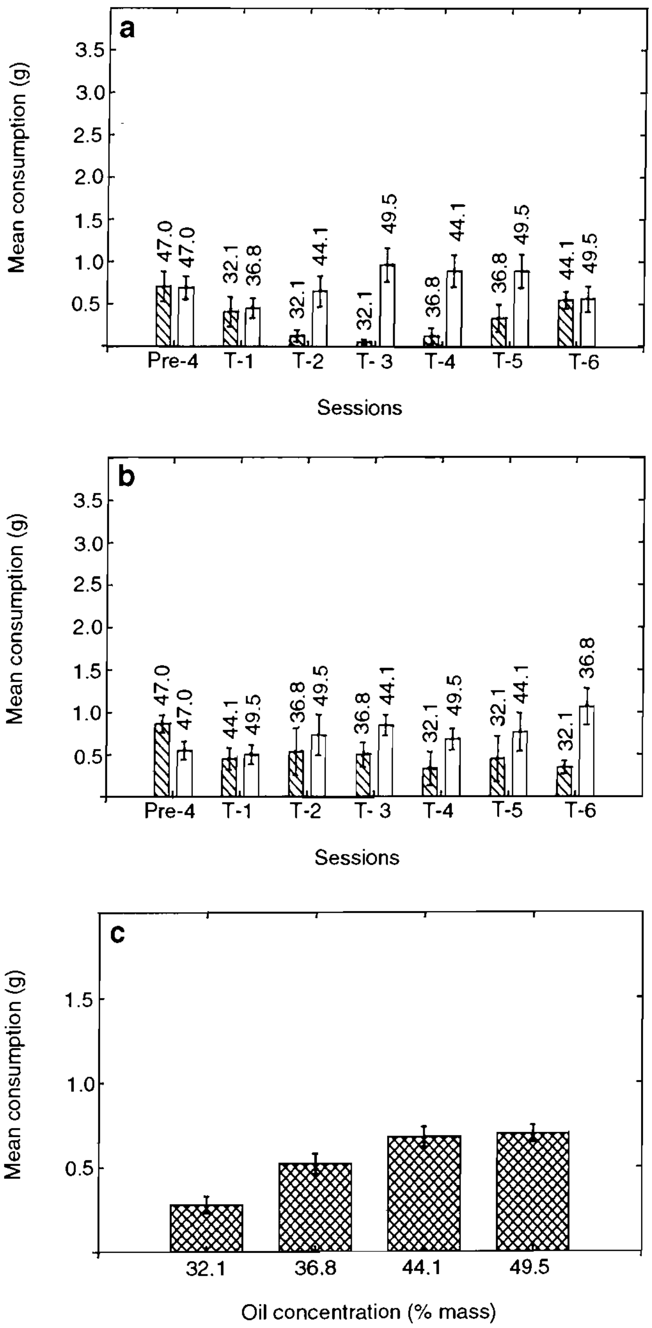

Figure 2. Experiment 2. a, Consumption of hulled, crumbled sunflower achenes by group 1 birds on pretreatment day 4 and treatment days 1–6. With the exception of pretreatment day 4 (Pre-4), striped bars represent consumption of the low-oil variety in each pair, while open bars represent consumption of the high-oil variety. b, Consumption of hulled, crumbled sunflower achenes by group 2 birds on pretreatment day 4 and treatment days 1–6. Striped and open bars represent consumption of low- and high-oil varieties, respectively, as described above. c, Overall mean consumption by both groups of all achene varieties, collapsed over time and presentation pairings. Numbers above bars represent achene oil concentrations (% g/g). Capped vertical lines represent standard errors of the means. Oil contents as in *Figure 1*

treatment period (those birds who completed treatment appeared in good health and were subsequently released). For group 1, there were significant differences among varieties ($F = 5.54$; 3,39 d.f.; $p < 0.01$). Average consumption of dehulled sunflower meats increased with increasing oil concentration (*Figure 2a*), and *post-hoc* tests revealed statistically significant differences between NdC and ST1 and ST2, and BRS and ST2. Total consumption during the 6-day treatment period did not differ among ($p > 0.50$) or within ($p > 0.50$) birds. However, average daily consumption during pretreatment (0.81 g) was less than that during treatment (1.01 g).

For group 2, there were no significant differences in consumption among varieties ($p > 0.40$), although mean consumption of high-oil (ST1, ST2) achenes was numerically higher than that of low-oil (NdC, BRS) achenes (*Figure 2b*). Not only was the range in average consumption much less than that for group 1, but there was not a direct relationship between percentage oil concentration and consumption. Variation in total consumption among days within birds was not significant ($p > 0.50$), and there was no significant variation in consumption among individuals ($p > 0.50$). None the less, average daily pretreatment consumption (1.08 g) was very similar to average daily treatment consumption (1.10 g).

When mean overall consumption of varieties was computed (*Figure 2c*), ranked and correlated with achene chemical characteristics, the same pattern of correlations as described for experiment 1 was obtained. Both oil content and gross energy were perfectly and positively correlated with consumption (r values = 1.0; 2 d.f.; $p < 0.0001$). Conversely, percentage ash and percentage crude protein were perfectly and negatively correlated with consumption (r values = -1.0; 2 d.f.; $p < 0.0001$). Neither percentage dry matter nor percentage acid detergent fibre were significantly associated with consumption ($p > 0.20$).

Discussion

In experiment 1, consumption was positively correlated with oil content and gross energy (cal g^{-1}), and negatively correlated with percentage ash and percentage crude protein. Both groups consistently discriminated between achenes that differed in oil concentration by 12%, and group 1 discriminated small differences at both low (4.7%; 32.1 vs 36.8% g/g) and intermediate (7.3%; 36.8% vs 44.1%) oil concentrations. These results suggest that red-winged blackbirds can discriminate between achene samples that differ in oil content by as little as 5% and that high-oil samples are preferred. In this regard, it is interesting to note that discrimination among intact achenes was superior to previously reported discrimination among oiled sunflower meal samples (Mason *et al.*, 1989a). It is also interesting that birds seemed unable to discriminate between high-oil achenes, even though the difference was 5.4%. This result suggests that there may be a 'threshold' oil concentration above which discrimination between samples is difficult or impossible.

That group 2 was apparently less sensitive than group 1 suggests that the order of varietal presentation was important. This finding was unexpected, but a plausible explanation can be offered. During the pretreatment period, a variety with high oil concentration (49%) was presented to both groups. However, during the treatment period, group 1 was presented with low to high oil concentrations whereas group 2 received the opposite. Possibly the sharp difference between pretreatment and treatment day 1 oil concentrations promoted more rapid acquisition of oil discrimination by group 1. If true, then learning (as well as sensory cues related to consumption, *per se*) may be important for discrimination.

In experiment 2, group 1 birds discriminated between oil concentrations of $\sim 12\%$ whereas group 2 birds failed to discriminate significantly, regardless of oil concentration. This difference in behaviour between groups is consistent with our speculation that order of presentation and learning may have influenced our results. More important, however, is the observation that birds in experiment 2 exhibited less overall sensitivity to differences in oil concentration than did birds in experiment 1. This result suggests that cues other than oil, *per se*, were at least partly responsible for discrimination among achenes. One possibility is that hull characteristics correlated with oil content served as cues in experiment 1 (Fick, 1978; Parfitt, 1984) but not in experiment 2. For example, high-oil achenes may be easier to hull, and thus may have been preferred because of relatively short handling times (Greig-Smith and Crocker, 1986). Alternatively, because achene meats were crumbled in experiment 2, it may have been that textural characteristics that reflect oil were eliminated in the second experiment. Finally, birds may have used subtle visual cues (e.g. size, colour) in experiment 1 that were absent in experiment 2. This possibility seems unlikely: achenes of all varieties except BRS were of the same approximate size and colour. It is important to note that when overall experiment 2 consumption was correlated with achene chemical characteristics, both oil content and gross energy were positively correlated with intake. Thus, although analysis of consumption failed to reveal significant differences, it is possible that the same chemical features of achenes played a part in guiding behaviour in both experiments.

Whatever cues or learning mechanisms may have been used to discriminate among achenes, it is clear that red-winged blackbirds possess a finely tuned capability for evaluating the oil concentrations of foods, even at the first feeding. Although differences in testing paradigms among species exist, the available evidence suggests that red-winged blackbirds are as capable as, if not superior to, rats (Naim, Brand and Kare, 1987) and humans (Mela and Christensen, 1987) in discriminating oil concentration.

Management implications

Our findings are consistent with the view that low oil content [or hull characteristics correlated with low oil content, e.g. hardness or thickness (Fick, 1978; Parfitt, 1984)] may explain much of the reduced damage observed for 'resistant' sunflower cultivars (Mason *et al.*, 1989a). The authors speculate that achenes of these cultivars are rejected primarily because they represent a lower-quality food (relative to other sunflower varieties), and not because they possess aversive qualities, *per se*. In future work to develop resistant sunflower varieties, multiple phenotypic characteristics (e.g. maturation rate, head curvature, achene density) should be examined simultaneously in varieties of similar oil content to assess whether the interaction of such factors may influence bird damage. Investigations of this type have suggested methods to reduce bird damage to existing commercial varieties of maize (Dolbeer, Woronecki and Stehn, 1982; Dolbeer *et al.*, 1988). In the short term, by examining bird damage to existing commercial sunflower varieties in relation to a variety of plant characteristics, it may be possible to provide growers with practical recommendations about which sunflower varieties to plant when bird damage is of concern. In the long term, correlations between bird damage and plant phenotype can be used to guide the efforts of plant breeders in the development of new bird-tolerant varieties.

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